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Abstract

This paper uses a dynamic macro-micro framework to evaluate the potential distributional effects of the expansion of the Panama Canal. The results show that large macroeconomic effects are only likely during the operations phase (2014 and onward), and income gains are likely to be concentrated at the top of the income distribution. The additional foreign exchange inflows during the construction and operations phases result in the loss of competitiveness of non-Canal sectors (Dutch disease) and in higher domestic prices, which hurt the poorest consumers. In addition, the construction and operation activities increase demand for more educated non-farm formal workers. Although these changes encourage additional labor movement out of agriculture and from the informal to the formal sector, much of the impact is manifested in growing wage disparities and widening income inequality. Using the additional revenues of the Canal expansion in a targeted cash transfer program such as "Red de Oportunidades", the Government of Panama could offset the adverse distributional effects and eradicate extreme poverty.

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Distributional Effects of the Panama Canal Expansion♦

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1. Introduction

Within the next four years, the output capacity of the Panama Canal will roughly double as a new set of locks is installed, enabling ships larger than the current Panamax standard to transit the Canal. Several studies (ACP, 2006a; IMF, 2007) anticipate significant employment creation and growth effects of the Canal expansion through increased domestic resource utilization and large multiplier effects. This view, however, is not consistent with the long-standing characterization of Panama as a dual economy, where a dynamic services exports sector has few linkages with the rest of the economy. More importantly, the methodology of these studies cannot provide insights into the potential distributional consequences of the Canal expansion—an aspect of crucial importance in Panama where inequality is a serious concern.

This paper adopts a methodological framework that is focused on the likely effects of the Canal expansion on the distribution of income . The findings of the paper are obtained by linking a dynamic computational general equilibrium (CGE) model of Panama with a micro-simulation framework based on a recent Panamanian household survey. The objective of the simulations is to contrast the counterfactual income distribution that would have resulted in the absence of the Canal expansion project with the income distribution resulting from the Canal expansion during both the construction and operation phases. Compared to earlier studies, this framework is much less suited for comprehensive growth analysis, especially in the near to medium term; on the other hand, it has the advantages of explicitly recognizing the inter-sectoral linkages in Panama's economy, clearly identifying the income sources of households, and providing a direct mapping of changes in macroeconomic aggregates to household welfare. Thus, it is important to interpret the results of this paper not as forecasts, but as a consistent set of scenarios for the likely poverty and inequality consequences of the Canal expansion.

The paper is organized as follows. The next section discusses the data and presents some background information on Panama and the Canal shock. Section 3 summarizes the model framework, while section 4 discusses the macro and micro results of our simulations. Section 5 offers concluding remarks.

2. Background

2.1. Panama before the Canal Expansion

Panama has been often characterized as a dual economy, consisting of a dynamic, high-wage export-oriented segment and a rigid, low-earning domestic-oriented segment.[1] Service sectors dominate Panama's economy, accounting for 77 percent of total value

[1] The data used in this exercise come from an updated 2003 Social Accounting Matrix (SAM) for Panama as well as two Encuesta de Condiciones de Vida (ECV) Panama household surveys for 1997 and 2003. The SAM has been constructed specifically for the purposes of this paper, with particular attention devoted to the identification of labor and capital remuneration in both formal and informal activities (Annex 1). Furthermore, considerable efforts have been devoted to improving consistency between macro (SAM) and micro (survey) data, although a full reconciliation of the two data sources remains beyond the scope of this paper. The SAM data is summarized in the table presented in Annex 1, which shows the structure of final demand and value added at the level of SAM accounts.

added and 59 percent of total exports.[2] The Canal sector is part of the dynamic, export-oriented services sector, accounting for one-fifth of Panama's exports, but only for 6 percent of total value-added and 0.5 percent of total employment. The sector operates as an enclave with few linkages with the rest of the economy: it exports all of its output, and its purchases of intermediate inputs (many of which are imported) are just 21 percent of its total production. Furthermore, its few workers are highly paid with average earnings 10-20 times the national average (Table 1).

Table 1 Average wages by activity and skill level, 2003 (000 balboas)

	Unskilled	Skilled
Agriculture	1.95	4.02
Non-agriculture	3.07	8.85
Informal (excl. canal)	1.70	1.75
Formal (excl. canal)	4.35	9.63
Canal	24.94	171.93

There are several other elements to the duality of the Panamanian economy. Farm activities account for more than 21 percent of total employment but just 8 percent of total value added, and farm labor market is segmented from the market for non-farm labor (see more details below). Similarly, informal activities (excluding agriculture) contribute just 6 percent to total value added yet 30 percent of workers earn their wages in the informal sector. Imports account for less than 10 percent of total purchases of agricultural products and services, while more than half of all demand for manufactured goods is satisfied through imports.

The same dichotomous structure is evident in the distribution of income in Panama. At the bottom end of the income distribution, poverty is concentrated among households earning their incomes from agricultural activities, and practically all of the indigenous households are poor (Table 2). Despite the nearly 10 percent increase in real GDP per capita between 1997 and 2003, the poverty profile of Panama has hardly changed: the headcount ratio for extreme poverty passed from a level of 18.8 percent in 1997 to a final value of 16.6 percent in 2003. Taking into account the 12 percent population growth over the entire period, just 5,500 people escaped poverty in 6 years. When poverty is defined using the moderate poverty line, the picture is even worse: while the headcount ratio for moderate poverty hardly changed between 1997 and 2003, the absolute number of poor increased by more than 100,000 persons. Finally, the indigenous community—already the poorest social group in Panama—experienced the most marked deterioration in its living standards as their per capita consumption actually declined relative to the 1997 levels.

[2] These and other shares reported in the text are calculated using the estimated SAM for Panama. The definition of service sectors excludes the Colon Free Zone but includes the Canal services.

Table 2 Incidence of Poverty among the Different Population Subgroups

Population Subgroups	Population	Per-Capita Consumption (Balboas)	Skilled Population (%)	Extreme Poverty (%)	Moderate Poverty (%)
1997					
Non-Agricultural Formal	970,524	2,551	32	3.8	17.7
Non-Agricultural Informal	1,095,408	1,860	22	10.5	29.8
Agricultural	461,532	859	4.9	40.1	70.6
Indigenous	205,675	330	2.3	86.3	95.4
Total	2,733,139	1821	21.2	18.8	37.3
2003					
Non-Agricultural Formal	985,429	2631	35.3	3.7	17.7
Non-Agricultural Informal	1,310,731	1904	25	6.7	28.7
Agricultural	530,514	961	8	32.1	65.1
Indigenous	236,800	310	5.7	90	98.4
Total	3,063,474	1851	23.9	16.6	36.8

* Notes: The figures are computed using the ECV (*Encuesta de Condiciones de Vida*) databases for years 1997 and 2003. The unit of analysis is the household and the welfare measure is consumption per capita. The extreme and moderate poverty lines are equal to 533 Balboas and 953 Balboas, respectively, which correspond to the official poverty lines used by the government of Panama. Informality is defined as the employers and employees in firms with less than 6 workers that do not contribute to the social security system, non-professional self-employed, and household workers. A worker is classified as skilled when he/she completed at least one year of secondary school.

Table 2 shows that the fastest-growing population group in Panama has been non-agricultural informal workers (an increase of 20 percent), while the number of people earning their primary income from formal activities hardly changed. Since wages in informal activities are significantly below formal earnings (Table 1), it is perhaps not surprising that, as the proportion of non-farm informal population rose, the incidence of moderate poverty among non-agricultural workers increased from 15.3 percent to 20 percent during this period. Hence the period was characterized by what Ravallion, Chen and Sangraula (2007) call the *urbanization of poverty*, with internal migration resulting in reductions in rural poverty, an increase in urban poverty, and little to no overall poverty effects.

2.2. The Canal expansion

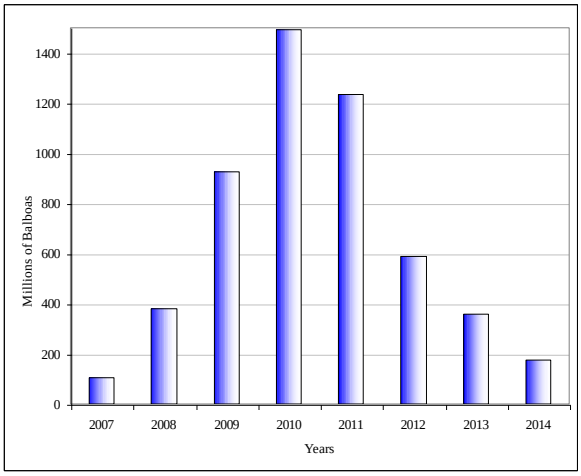
The expansion of the Canal appears to be a large 'shock' for Panama, with the total cost of the investment project estimated to reach 5,250 million balboas (approximately 40 percent of GDP in 2003).[3] However, the year-by-year impact of the surge in investment is likely to be much smaller because the construction activities will take place over a 7 year horizon (Figure 1). Furthermore, Panama's real GDP has been growing at an average annual rate of 8.0 percent per year between 2003 and 2010, and growth is expected to decelerate only slightly in the short- and medium-term. Taking into account these growth

[3] This estimate is provided by the Panama Canal Authority in its document on the expansion of the Canal. The full document can be found here: http://www.pancanal.com/esp/plan/temas/plan-maestro/ .

projections, the additional investment in the Panama Canal is estimated to reach just 8 percent of GDP during the peak spending year of 2010, while the average spending over the entire construction period is less than 4 percent of GDP.

At the sectoral level, the Canal expansion creates additional demand for only two types of activities in Panama: construction and capital goods. According to the initial structure of the investment demand, one additional Balboa spent of the Canal investment generates 64 cents of additional demand for construction (which is almost entirely domestic) and 36 cents for capital goods (which are mostly imported). Although these sectors generate demand throughout the economy (the multiplier effect), the limited linkages of the Canal with the rest of the economy restrict the ability of the investment spending to energize the entire economy.

Figure 1: Expenditures for the Canal expansion are spread over 2007-2014



Source: Panama Canal Authority (2006) Master Plan, Chap.9

3. A CGE-Microsimulation Model for Panama

Given the vast differences in earnings across sectors and the semi-isolated status of the Canal in Panama's economy, this paper adopts a structural macro-micro model to capture both the direct and indirect impacts of the Canal expansion on the income distribution. The expansion directly affects those who receive an income from the construction and operation of the Canal, but this group represents a fairly small portion of the total employment and includes very few poor and no indigenous persons. Thus, the potential impacts of the Canal expansion on the income distribution are likely to be mostly second-order, general equilibrium effects. These can be grouped into four major categories: a) changes in real income growth, b) changes in factor markets (employment, wages, and rental rates), c) changes in prices of consumer goods, and d) use of the government receipts from the new Canal.

The methodological approach of this paper can be best described as a two-step process. In the first step, a CGE model is used to create two scenarios, one with a new expanded Canal and the other without. In the second step, the four sets of general equilibrium effects identified above are mapped to households in a microsimulation model. This procedure generates macro and micro counterfactuals which can then be used to estimate the effects of the Canal expansion on the distribution of incomes.

The approach of this paper is based on ex-ante macro-micro simulation methodologies developed in the recent literature: Bourguignon, Bussolo and Pereira da Silva (2008) describe its advantages and drawbacks. Variants of this methodology have been used in various case studies, including Bourguignon and Pereira da Silva (2003), Ferreira and Leite (2003), Chen and Ravallion (2004), and Bussolo, Lay, and van der Mensbrugghe (2008). ehe present paper belongs to the long literature on welfare effects of large infrastructure projects. Exploiting the fact that river gradient affects a district's suitability of dam construction, Duflo and Pande (2007) find that such infrastructure projects in India increase agricultural productivity in villages located downstream from the dam. Using a difference-in-difference approach, Lokshin and Yemtsov (2005) find that improvements in school and road infrastructure increase welfare among the poor in Georgia. Using a variety of GMM estimators on a panel data including over 100 countries covering the period 1960-2000, Serven and Calderon (2004) show that infrastructure development can be highly effective for poverty alleviation. Our approach differs from existing papers in two important ways: (1) the CGE-microsimulation model developed here allows capturing the economy-wide effects of the Canal expansion without losing the heterogeneous impacts on different households; (2) based on stylized facts, we assume that the Canal is a separate sector with only marginal linkages with the rest of the Panamanian economy, hence having marginal, if any, effects on total factor productivity.

3.1. Macro framework

The CGE model used in this paper is the World Bank's prototype single-country model.[4] Production takes place under perfect competition and constant returns to scale, and is modeled in a nested constant elasticity of substitution (CES) fashion to reflect various substitution possibilities across inputs (see Figure 2). While the production nesting for the canal sector is similar to other activities, we assume that the canal uses a Leontief technology and employs a canal-specific capital stock. All labor and capital income accrues to the households, with the exception of capital income from publicly-owned enterprises (e.g., the canal sector).

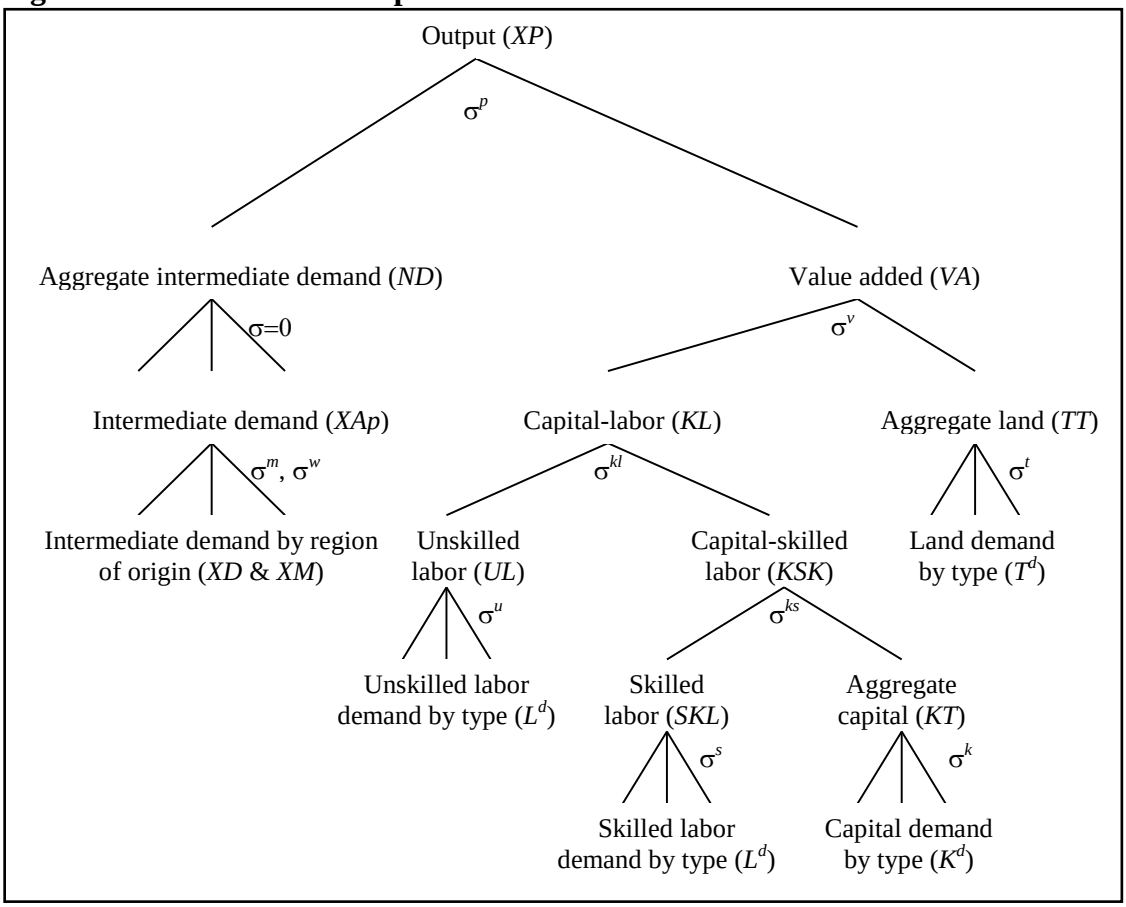
The model differentiates between formal and informal production activities, with the latter having no access to financial markets or public services. The output of these activities is transformed into consumed commodities by means of a transition matrix, which takes into account the fact that multiple activities can produce the same commodity (e.g., construction services can be provided by both the formal and informal sectors) and that multiple commodities can be the output of a single activity (see Annex 4 for a full listing of commodities and activities in the model). Household demand is allocated across commodities according to the linear expenditure system (LES), in which consumers maximize a Stone-Geary utility function subject to the disposable income constraint.[5] Other final demand agents—government and investment—use the CES expenditure system.

[4] See Annex 4 for model equations. Detailed model documentation and the user's guide are available in van der Mensbrugghe (2005b) and van der Mensbrugghe (2005a), respectively.

[5] See Deaton and Muellbauer (1980, Chapter 3) for a detailed discussion of the LES demand system, and Stone (1954) for the Stone-Geary utility function.

International trade is modeled using the nested Armington specification, in which consumer products are differentiated by region of origin and combined using CES functions.[6] World import prices are fixed, which means that any increase in import demand can be satisfied without affecting global prices (small country assumption). On the supply side, producers allocate output to domestic and export markets the model according to a constant elasticity of transformation (CET) specification. With the exception of the canal sector, where Panama has monopoly power and therefore faces a downward-sloping demand curve, the export price elasticity of demand is infinite. Demand for canal services also responds to the growth in global trade by shifting outward in every time period.

Figure 2 Nested structure of production



The aggregate stock of capital is allocated across various sectors with a finite elasticity of transformation, resulting in imperfect mobility of capital. Skilled workers are freely mobile throughout the economy, while the market for unskilled labor is segmented into farm- and non-farm categories. Within each segment, labor is perfectly mobile across activities, but mobility across segments is limited by a migration function which responds to changes in the farm/non-farm wage premia. The initial level of migration is calibrated at 2 percent of the farm sector labor force, consistent with the migration levels recorded

[6] See Armington (1969).

in Panama over the 1997-2003 period. Although international migration is likely to be an important element in the dynamics of the Panamanian labor market, it is not considered in this analysis due to the difficulties of modeling this flow in a single-country setting. Labor mobility across formal and informal activities is not limited, but informal workers earn significantly lower salaries (on average, 20 percent of formal sector wages), giving rise to potentially large productivity effects when demand for one of the activity types rises. Finally, the model assumes no change in the degree of resource utilization, or fixed employment. This assumption is consistent with the available econometric evidence for Panama (see Galliani, 2006), which shows that the unemployment rate has been fairly steady at around 6 percent and has not changed much during economic upswings or downturns.

The volumes of government current and investment spending (including investments in the canal) are fixed as shares of real GDP, while the deficit (in real terms) is also fixed. Public revenues adjust to clear the government balance by means of a flexible household direct tax rate.[7] The investment-to-GDP ratio is fixed at the base year value and a flexible marginal propensity to save out of household disposable income ensures that total saving equals total investment. The current account balance is fixed by the available quantity of foreign saving and the exchange rate is the numeraire, which means that domestic prices are determined relative to a fixed-cost basket of foreign goods.[8]

The model is solved in a recursive dynamic mode, in which subsequent end-of-period equilibria are linked with a set of equations that update the main macro variables. There are three determinants of real GDP growth in the model: labor supply growth, capital accumulation, and increases in productivity. The volumes of both types of labor grow exogenously at the rate of growth of the working age population (ages 15-64), obtained from World Bank population forecasts. The capital stock in each period is the sum of depreciated capital from the period before and new investment. For all sectors, capital productivity remains fixed throughout the model horizon, while growth in labor productivity in the business-as-usual (BaU) scenario is calibrated to real GDP growth in the World Bank's medium- and long-term forecast for Panama.[9] In all other scenarios, labor productivity is fixed in each period at the BaU level, and GDP growth becomes endogenous.[10] Thus, real GDP growth may differ from BaU due to faster/slower accumulation of capital or shocks to the productivity shift parameters, allowing the variations in GDP growth across scenarios to be directly attributed to the simulated policy reforms.

[7] Although other assumptions about closing the government balance, such as adjustments in indirect taxes, increased borrowing, or reduced spending, are also plausible, choosing the direct tax rate as an instrument is a fairly neutral way (in an allocative sense) of restoring fiscal balance in case of a shock. It also simplifies welfare measurements since the incidence of making up the budgetary shortfall falls squarely on consumers (in contrast to indirect taxes, which, for example, may motivate producers to allocate a larger share of production toward exports which may be taxed at a lower rate).

[8] We use the deflator of GDP at factor cost as a measure of movements in the real exchange rate.

[9] Labor productivity growth in the canal sector is always exogenous.

[10] Thus, in the absence of any shocks, the BaU GDP growth rate is reproduced exactly.

3.2. The micro module: linking household surveys to the CGE model

The poverty and distributional effects of the Canal expansion are estimated using a top-down approach. The top CGE-generated prices and labor reallocation are used to 'shock' the bottom micro module so that a counterfactual income distribution can be estimated. No feedback from the micro module to the macro model is explicitly accounted for in this model. The following equations represent the core of the micro module:

$$Y_h = \sum_l \theta_{h,l}^{\ell} w_l + Y_h^o \qquad (1)$$

$$\frac{\Delta W_h}{Y_h} = \sum_g - \theta_{h,g}^{c} (\Delta p_g) + \sum_l (\Delta \theta_{h,l}^{\ell})(\Delta w_l) \quad (2)$$

Income of household *h*, Y_h, is defined as the sum of labor remunerations, $(\sum_l \theta_{h,l}^{\ell} w_l)$, and an exogenous, non-labor income (Y_h^o). Welfare effects are approximated by changes in real household incomes which, in turn, depend on: 1) changes in the prices of purchased goods (Δp_g) and the initial share of expenditure on each good $(\theta_{h,g}^{c})$[11]; 2) changes in the returns to skilled and unskilled labor in the different labor market segments (Δw_l); and 3) changes in the allocation of workers in the different labor market segments, i.e. agricultural and non-agricultural sectors as well as formal and informal activities within urban areas $(\Delta \theta_{h,l}^{\ell})$. A new household welfare aggregate is computed based on the sum of the exogenous income plus the *simulated* labor income for each member of the household given his or her skill endowments and sector of employment. Based on the simulated welfare aggregate, a counterfactual distribution of income is generated and compared with the initial distribution.

A key issue in this modeling framework is the connection between the macro CGE part and the micro module and therefore a major difficulty consists of satisfactorily mapping the sources of incomes from the CGE model to the micro model. For example, in the CGE model it is possible to clearly distinguish labor remunerations from capital earnings; however, in the micro data, for the large group of self-employed people, incomes are a mix of labor and capital returns. For this group, an imputed wage is estimated and the remaining amount is classified as capital income (see Annex 2 for details). Furthermore, the micro-simulation module defines an exogenous household income (Y_h^o) as all non-labor income components like transfers, imputed rents, capital remuneration, etc. This exogenous income is not modified during the simulations. Thence, although consistency between macro and micro is always pursued, the changes in capital remunerations predicted by the CGE are not reflected in the micro data. The

[11] For simplicity we only distinguish between food and non-food products.

decision to treat capital remunerations as exogenous and hence losing some of the macro-micro consistency conforms to the limitation of household surveys to capture incomes deriving from capital (see Szekely and Hilgert, 1999).

A structuralist feature introduced in the model is the assumption of labor market segmentation. Some degree of labor segmentation is allowed between agricultural and non-agricultural sectors and, within urban areas, between formal and informal activities. The labor market segmentation assumption gives rise to wage differentials across labor market segments.[12] At the micro level workers are reallocated among agriculture, non-agriculture informal, and formal activities by means of a probit model where the probability of switching sectors is estimated as a function of several personal and household characteristics (see Annex 3 for the complete list of variables used in the model and its results). Workers are allowed to switch between the different labor market segments until the CGE-predicted labor allocation is achieved. For those workers who switch, a labor income is imputed on the bases of worker's observable characteristics and the return of them prevailing in the receiving labor market segment.

The top-down approach used here takes into account important sources of household heterogeneity such as the structure of income by labor segment and the composition of consumption by commodity—the various θ's in the above equation. In other words, although there are only a handful of variables linking the macro and the micro, these shocks will have a different welfare impact across households. Additionally, allowing for full heterogeneity means that in the new, *simulated*, distribution, households, as well as individuals, can be identified according to the complete set of socio-economic characteristics recorded in the survey. It is thus easier to identify a specific characteristic – such as region of residence, employment status, gender, education, age, etc. – that may strongly correlate with larger than average losses from the Canal expansion and then use this information in targeting compensatory measures.

4. What If Panama Expands Its Canal? Macroeconomic and Distributional Impacts

This section contrasts a Business-as-Usual (BaU) scenario with a Canal expansion scenario to assess the potential effects of the Canal expansion project on real GDP and its components, the real exchange rate, the labor markets, and the government budget. The dynamic macro-micro simulation framework used here is not a forecasting tool so the emphasis is mainly on the differences between the BaU and the canal expansion scenario. These differences tend to be robust in that they do not change much with variations in the assumptions and dynamic paths of the exogenous variables used in the BaU scenario. In other words, the value added of the modeling exercise does not consist of forecasting the future level of specific variables, but rather to show how those levels are *ceteris paribus* changed by the expansion and operation of the Canal.

[12] The Chow tests for equality on the Mincer-equation parameters between agricultural and non-agricultural sectors and formal and informal activities within urban areas were rejected at the 99 percent level of confidence. This is strong evidence supporting labor market segmentation.

4.1. Macroeconomic results

Business-as-usual scenario with no Canal expansion

The behavior of macroeconomic variables in the BaU scenario is summarized in Table 3. The results are reported separately for two periods: 2003-2014 and 2014-2020, with the first period characterized by rapid growth in real income and the second period exhibiting a marked slowdown to a more sustainable, lower growth path.[13] In the second period, exports growth slows down relative to imports as the real exchange rate experiences a more marked appreciation. This is determined mainly by the dynamics of productivity growth, which drives the strong growth performance during the first period and slows down rapidly in the later years.[14] In the high growth period, increases in productivity help keep output costs down and buttress the competitiveness of Panamanian producers vis-à-vis foreign firms. During the transition to slower growth, smaller annual improvements in labor productivity imply that more workers are needed for a given increase in output, driving up labor costs and eroding the competitiveness of Panamanian products versus foreign-made goods. Finally, as explained in the previous section, public consumption and public and private investment remain fixed as a share of real GDP in every year of the BaU scenario.

Table 3 Macroeconomic variables

	Initial levels (bn lcu)	Average annual growth (%)			
		BaU		Canal	
	2003	2003-14	2014-20	2003-14	2014-20
Real GDP at market prices	12,933	5.36	3.06	5.37	3.68
Private consumption	8,016	5.40	3.03	5.42	3.92
Public consumption	1,807	5.36	3.06	5.36	3.06
Investment	2,457	4.92	2.89	5.33	3.08
Non-canal investment	2,120	5.36	3.06	5.37	3.68
Canal investment	87	5.36	3.06	12.86	-2.36
Stock changes	249	0.00	0.00	0.00	0.00
Exports	4,425	5.32	3.54	5.22	4.22
Imports	-3,771	5.14	3.44	5.26	4.15
Real Income per capita	3,790	3.81	2.02	3.83	2.60
	End-of-period values (for the corresponding periods)				
Real exchange rate	1.00	1.012	1.066	1.015	1.108
Welfare (EV)				25	1,266
Trade-to-GDP	63.4	61.8	59.6	61.5	58.0
Food CPI	1.000	1.011	1.050	1.014	1.075
Non food CPI	1.000	1.011	1.062	1.013	1.099

The evolution of factor markets matters not only for the external competitiveness of Panama but also for its pattern of sectoral specialization. Several major trends are observed in the BaU scenario and summarized in Table 4: acceleration of skilled wage

[13] In the Canal scenario, the first period also corresponds to the construction phase and the second period to the operation phase.

[14] The model assumes that all technological change is Harrod-neutral, i.e. labor-augmenting.

growth relative to the wages of unskilled workers, gradual reduction in farm employment, pronounced decline in capital rental rates during the second period, and a reduction in the share of formal activities during the first period followed by increased formalization in the second. The increasing skill premium can be largely explained by the differences in labor supply and labor demand. The scenarios considered in this paper do not incorporate increases in the average educational attainment over time, which means that the stock of both skilled and unskilled workers grows at the same rate as the working age population. On the other hand, demand for skills rises over time as Panama shifts out of unskilled-intensive activities like agriculture and into more skill-intensive manufacturing and services.[15] This transition is consistent with econometric evidence that food income elasticities tend to be below one; it also results in a relative increase in demand for skilled labor and widening of the skilled wage premium.

Table 4 Factor markets

	BaU	BaU		Canal	
	2003	2003-14	2014-20	2003-14	2014-20
	Levels	Annual growth rates (%)			
Unskilled wage	2.70	3.51	2.1	3.57	3.3
Non-farm unskilled wage	3.07	2.84	1.7	2.90	3.0
Farm unskilled wage	1.95	4.91	3.3	4.96	3.9
Skilled wage	8.68	4.28	5.7	4.33	8.2
Formal capital real rent (index)	1.00	-0.36	-2.2	-0.35	-2.6
Informal capital real rent (index)	1.00	0.85	-3.8	0.87	-5.8
Canal capital real rent (index)	1.00	-0.11	-1.1	-0.20	0.3
Total labor supply	1,178	1.6	1.3	1.6	1.3
Unskilled labor	713	1.6	1.3	1.6	1.3
Unskilled farm labor	236	-0.4	-0.4	-0.4	-0.5
Unskilled non-farm labor	477	2.5	1.9	2.5	2.0
Unskilled formal non-farm labor	217	2.2	3.2	2.3	3.5
Unskilled informal non-farm labor	260	2.7	0.8	2.6	0.6
Unskilled migration	5.2	-2.0	-1.6	-2.0	-0.8
Skilled labor	465	1.6	1.3	1.6	1.3
Skilled formal non-farm labor	365	1.7	1.8	1.7	1.8
Skilled informal non-farm labor	84	1.3	-0.9	1.2	-1.0

The structural shift out of agriculture is also driven by falling farm employment, which declines at an average rate of 0.4 percentage points per year. This is consistent with the experience of Panama between 1997 and 2003, when the rates of worker migration to non-agriculture activities outpaced the growth rate of farm labor force. As a result of relative labor scarcity in agriculture, farm wages actually grow faster than non-farm wages in the BaU scenario, reducing the non-agriculture wage premium to 15 percent in 2020 from 58 percent in 2003.

The changes in consumer prices (reported in the bottom part of Table 3) are mainly determined by the trends in agriculture production and demand for food products.

[15] The contribution of agriculture to total output declines from 7.3 percent in 2003 to 6.2 percent in 2014 and further to 5.6 percent by 2020.

Between 2003 and 2014, slower-than-average growth rates of farm output and demand for agricultural goods offset each other, resulting in similar changes in food- and non-food prices. In the later period, slower growth in food demand outweighs smaller contributions of agriculture to total supply and food CPI increases less than the CPI for manufactured goods and services.

The changes in the share of formal activities and the behavior of capital rental rates are both linked to the slowdown in growth in the later part of the model horizon. Moving to a lower growth path means that the stock of capital accumulated during the period of high growth is too large, necessitating some shedding of capital (through accelerated depreciation) but also a decline in the rental rates. Since formal activities tend to be much more capital intensive than informal (see Annex 1), access to cheaper capital benefits the former more than the latter and leads the transition towards increased formalization. The opposite trend takes place in the early period, when formal activities find themselves at a cost disadvantage relative to the informal sector when the prices of skill-intensive financial services and public administration rise faster than the economy-wide average.

Because public services are much more skill-intensive than the economy-wide average (See Annex 1) and skilled wages grow faster than unskilled wages (Table 4), over time the government must increase its revenue collections to be able to fulfill its service delivery commitments. In our scenarios, this is accomplished by a combination of raising direct taxes (to finance the rising recurrent costs) and increased foreign borrowing (to finance capital projects, including investments in the canal sector). As a result, disposable income per capita grows at a rate slightly slower than real GDP per capita.

The Canal scenario

In the second scenario, public investment in the Canal is accelerated according to the PCA schedule (Figure 1) and is financed by borrowing on the international capital markets. During the construction phase, which takes place between 2007 and 2014, the yearly growth rate of the investment in the Canal more than doubles (Table 3) while Canal output remains the same as in the BaU scenario.[16] In the operation phase, when the new sets of locks come online in 2014, the output rises to twice the BaU levels.

In the construction phase, the growth rates of real GDP and private consumption barely accelerate relative to the BaU scenario. Therefore, unlike the views expressed in ACP (2006a) and IMF (2007), the construction of an expanded Canal has a very small growth impact in our model. This outcome can be explained by the following reasons. First, although employment demand in the construction sector goes up, new jobs in this sector amount to just 4% of the total unskilled employment and close to 2% of skilled employment even during the peak investment year of 2010.[17] The simple averages of the employment gains during the construction years are 0.9% and 0.4% for the unskilled and skilled segments respectively, which means that, despite a large increase in demand for construction services from the Canal project, relatively few jobs are created from the economy-wide perspective. More importantly, the new jobs in the construction sector are filled by workers leaving jobs in other sectors. Therefore, the assumption of a fixed unemployment rate is the main determinant of the lack of large growth effects during the Canal expansion. This assumption is consistent with the documented rigidities in

[16] The growth rate of Canal investment reaches almost 13 percent, up from 5.4 percent in the BaU.
[17] These percent increases include new informal construction jobs.

Panama's labor market and the fact that employment has been very slow to rise even during periods of economic boom (Galliani, 2006), but is at odds with the view of ACP (2006a) and IMF (2007), which expect employment to rise by 2-4% percent from the 2003 levels.

The second reason for not observing significant growth effects of the construction phase in our model is the assumption that the capital stock accumulated during the Canal expansion cannot generate any additional income flows until construction is completed by the end of 2014. Therefore, factors endowment in the first period of the canal expansion remains the same as in the BaU scenario and, if the canal investment does not generate any productivity spillovers, the only source of the marginal real income gains shown in Table 3 stem from re-allocation of resources into more productive sectors of the economy. This is indeed the case here, as Table 4 shows that demand for formal-sector labor—where workers are paid on average 5 times more than in the informal sector (Table 1)—accelerates in the Canal scenario relative to the BaU.

Even if real income growth remains largely unaffected during the construction phase, the increase in investment spending can have other relevant macroeconomic consequences. Among these, the risk of Dutch disease effects is frequently highlighted. The argument is as follows. In a case where all canal expansion-related financing is obtained in the form of foreign borrowing, as in the one simulated here, the larger inflows of foreign currency increase domestic demand, specifically investment demand for the expansion of the Canal. This additional domestic demand is satisfied by increased imports and increased domestic production of non-tradables (mainly construction services). Import prices are unaffected by the increased demand in Panama, whereas non-tradable prices, together with factor prices, will rise. This relative price shift results in a real exchange rate appreciation which in turns negatively affects exporting sectors. When comparing the Canal construction phase with the first period of the BaU, all these effects – stronger increases in factor and goods prices, faster real exchange rate appreciation, larger imports, and decreased exports – are observed in the model results, but their magnitude is rather small.[18] In particular, while the unskilled wages accelerate in the Canal construction phase relative to the BaU conditions (Table 4), the prices of food products (which represent a larger share of total consumption for the poor households) also increase faster than in the BaU (Table 3). This makes the poverty impacts of the Canal construction phase ambiguous. At the same time, although the direction in poverty changes is unclear from the macro results, the Canal construction project is almost certainly not having any *direct* poverty alleviation effects, and its *indirect* effects through changes in employment, factor, and goods prices are also likely to be limited.

The impact of public spending on poverty reduction during the construction phase is similarly small. Due to the acceleration in growth of prices and wages in the construction phase (the Dutch disease described above), the cost of providing public services during this period rises relative to the BaU scenario. As a result, the government requires higher

[18] The small magnitude of these effects is in turn explained by considering the limited size of the increased investment in the Canal and the same arguments used above in rationalizing the minor effects on GDP growth can be applied here. Besides, the leakages through imports are quite relevant in the Canal project shock: a large share of increased non-construction investments is satisfied by imports. Finally, inter-sectoral mobility of factors, quite high in the model assumption, helps to reduce factor price inflation and thus also moderates rises of goods prices.

direct tax revenues, which are obtained via a small increase in the household income tax rate.[19] This increase explains why per capita income accelerates less than real GDP (Table 3) during the construction phase, although the poverty impacts are likely to be very mild due to the small aggregate magnitude of the change.

What about the operation phase? According to the background studies of the Panama Canal Authority, the expanded canal becomes operational in 2015. At this date in the simulation model, the capital stock as well as the output of the canal sector more than double. Current available projections indicate that there will be enough demand for the expanded Canal but much less is known about the price elasticity of this demand. [20] In this particular market, Panama clearly operates in a monopolistic position which is reflected by a downward sloping world demand curve for the Canal services. However, from one year to the next, demand also shifts outward following the increasing trend of global trade. Depending on the relative sizes of the price elasticity of the demand for canal services and the outwards shifts of this demand curve, the dynamic path of the canal fees will be either growing or decreasing. Statistics on the recent years show that Panama has been able to raise the transit fees without affecting demand (see Latin Source, May 20, 2007) and the current simulation assumes that this trend continues in the future even with an expanded canal.

A major consequence of the new locks coming online is the acceleration in the yearly growth rate of real GDP to 3.7 percent from 3.1 percent in the BaU scenario. There are two major reasons for faster income growth during the operation phase. The first reason is the now larger (Canal sector-specific) capital stock, which raises the factor endowment of Panama and generates new income through higher Canal capacity and increased fees. The second reason is a boost in total factor productivity, which occurs as workers move from lower-productivity (and lower-paying) occupations into the canal sector, where both productivity and wages are high (Table 1). Furthermore, additional income growth generates more demand for manufactured goods and services (relative to agriculture) and encourages worker migration into non-farm occupations where productivity tends to be higher.

The Canal sector is skill intensive and the additional demand for skilled workers resulting from its expanded operation generates a significant increase in their wages (see Table 4). The Canal sector can afford to pay higher wages because higher wage costs are passed on to higher Canal fees with low or no effect on revenues. Higher skilled wages generate labor income gains which in turn increase domestic demand and benefit all workers.[21] For these reasons, wages of unskilled workers also rise, but the rate of increase in the earnings of unskilled employees falls short of the acceleration in skilled wages. As a result, the skill premium widens from 329 percent in 2020 under the BaU conditions to 360 percent in the same year in the Canal scenario. Even before moving to micro analysis, these results already indicate that the growth dividends of the Canal operation

[19] For example, the 2014 direct tax rate rises from 8.82 percent in the BaU to 8.85 percent in the Canal scenario.

[20] See Panama Canal Authority study ACP (2006a, b) and IMF (2007).

[21] Notice that workers in the Canal sector enjoy a large exogenous premium vis-à-vis the other sectors. Increased employment in the Canal and rising wages thus combine to produce a very significant gain of labor incomes for the household sector.

are likely to be unequally distributed, with the larger share of the gains accruing to the better-off parts of the population.

The wage pressures in the Canal operation phase push up domestic resource costs and are reflected in the real exchange rate appreciation shown in Table 3. Remarkably, the real exchange rate differential between the BaU and the Canal simulation is much higher in the operation phase than in the construction phase. In a way, the expanded operations of the Canal sector can be thought of as the discovery of a new natural resource for which there is an increasing world demand. The booming of the Canal service exports though has some unfavorable effects for the other tradable sectors. During this phase, other export sectors record lower growth rates, and import competing domestic sectors struggle against cheaper imports. As a result, Panama specializes further in exporting Canal services.

The additional real exchange rate appreciation and rising domestic costs of the Canal scenario are also evident in faster growth of consumer prices (Table 3). Although the prices of both food and non-food commodities accelerate relative to the BaU scenario, the increase in the non-food CPI is twice the increase in food prices. This is consistent with higher income elasticities for non-food products as well the higher skill content of non-agricultural goods. Unlike the changes in factor returns, the trends in consumer prices are likely to attenuate the tendency of the Canal scenario to favor richer parts of the population because food prices (the main consumption item of the poor) increase less than the economy-wide CPI.

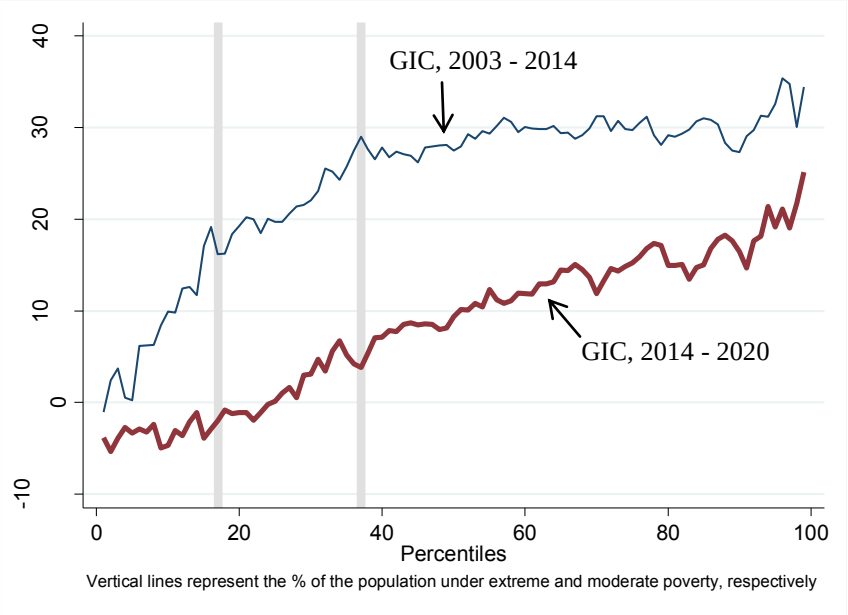
Turning now to the government accounts, two offsetting trends take place in the canal operations phase. On the one hand, the faster pace of income and wage growth in the operations phase (relative to the BaU scenario) mean that public expenditure must rise significantly in order for the government to maintain the same level of public service delivery as in the BaU. On the other hand, a large part of the increased expenditure can be funded by higher canal revenues, as well as increased indirect tax collection. As a result, the government can increase the size of its income transfers to households by 273 million balboas in 2020 (through decreased direct taxation). This transfer leads to a faster pace of growth in household disposable income and contributes to the sizable welfare gains observed in this scenario (Table 3). The revenue effect also has potentially important distributional effects: while in the macro part of our model, we assume that the gains are distributed uniformly across all households, our micro model allows for exact targeting of any potential public program (e.g., similar to the existing cash transfer program) that might seek to redistribute the canal revenues to the poorer parts of the population.

4.2. Distributional Impacts of the Canal Expansion

As described above, two quite different periods characterize the BaU scenario. During 2003-2014, strong growth and minor distributional effects result in significant poverty reduction. Conversely, a sluggish growth combined with an increase in inequality lead to almost no change at all in poverty incidence between 2014 and 2020 (see Table 5). Neither of the two periods is characterized by a strong labor reallocation: movement

of workers out of agricultural activities[22] continues at a slow rate and informality in non-farm employment stabilizes at around 40 percent.

Figure 3 Growth Incidence Curves (GIC) for the Business as Usual scenario



The distributional effects of the different pattern of growth of the two periods are graphically summarized by the growth incidence curves (GIC) shown in Figure 3.[23] In the BaU scenario, between 2003 and 2014 real average incomes for the median household in Panama will cumulatively increase by 27.5 percent. This gain is not evenly distributed: incomes of the bottom 10 percent of the distribution will rise only 4.3 percent on average compared to an increase of 32 percent experienced by households located at the top 10 percent of the distribution.

An even more regressive effect is found in the BaU scenario for the second period. The median income increases 9.4 percent with respect to 2014, but incomes at the bottom 10 percent of the distribution decrease 3.7 percent whilst incomes of the richest 10 percent of the population rise almost 20 percent. The regressive income effect shown by the GICs in Figure 3 is explained by an increase in the wage gap between skilled and unskilled workers. In both sub-periods, real wages of unskilled workers in non-agricultural sectors – the largest labor segment group – experience the slowest growth rate. As a result of the increase in the wage differentials, household income distribution deteriorates as it is indicated by the increase in the Gini coefficient reported in Table 5.

[22] The CGE model does not explicitly account for rural to urban ('geographic') migration of workers, but only for agriculture to non-agriculture ('inter-sectoral') labor reallocation. Only the first type of workers' movement can be defined as internal migration and precisely linked to urbanization. However, in the main text, due to the high correlation (0.58) between working in non-agricultural sectors and being located in urban areas, the terms sectoral reallocation and urbanization are at times used interchangeably.

[23] The GIC is shows the changes in welfare along the entire income distribution, therefore capturing, in a single graph, the growth and distributional components of overall welfare changes. For a detailed description of the properties characterizing the growth incidence curves see Ravallion and Chen (2003)

Table 5 Poverty and Distributional Effects under the BaU and Canal Scenarios

Welfare Indicator	Observed (2003)	BaU 2014	BaU 2020	Canal – BaU (2014)	Canal – BaU (2020)
Average Real Income	2,490	3,219	3,725	6	243
Poverty Headcount Ratio (%)					
Extreme	16.6	12.9	13.3	-0.07	0.0
Moderate	36.8	28.3	27.5	-0.08	-0.3
Poverty Gap (%)					
Extreme	6.4	5.2	5.4	0.0	0.10
Moderate	15.2	11.9	12.0	0.0	0.06
Gini Coefficient	56.8	57.7	59.8	0.0	0.7

* Notes: Authors' own estimation using data from LSMS 2003 and the results from the CGE-micosimulation model for Panama. The extreme and moderate poverty lines are equal to 533 Balboas and 953 Balboas, respectively, which correspond to the official poverty lines used by the government of Panama.

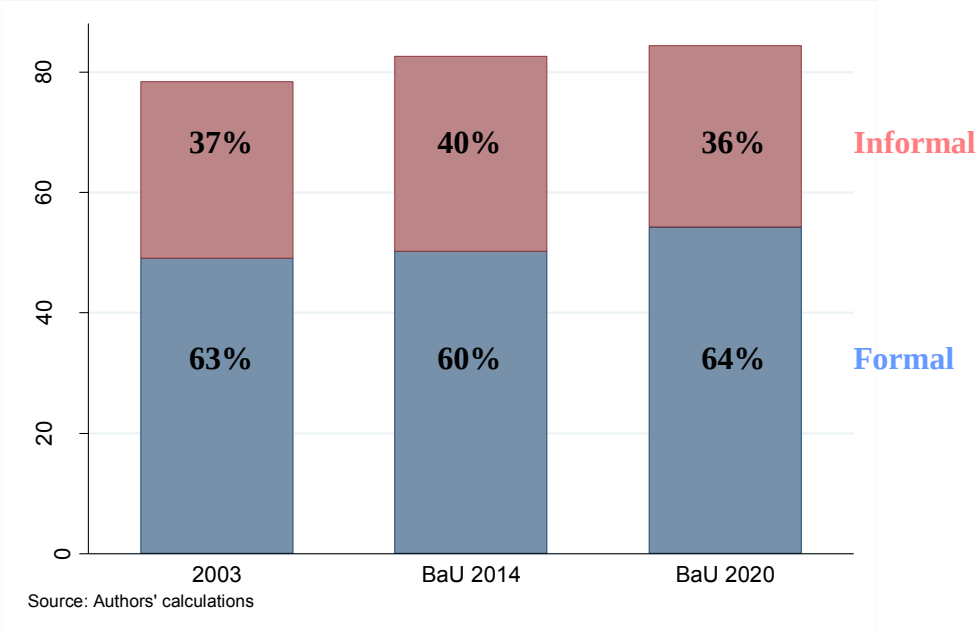
Labor reallocation, between agricultural and non-agricultural sectors and, within the latter, between formal and informal activities also plays a relevant role in reshaping income distribution. In the BaU scenario, the process of urbanization mentioned in section 2 continues during the period 2003-2020 with the share of workers in non-agricultural activities increasing from 78.5 percent in 2003 to 82.7 percent in 2014 and finally reaching 84.4 in 2020 (Figure 4). Movement of unskilled workers out of agricultural activities creates pressure for job creation in the non-farm, mainly urban, segment of the economy. If not enough formal jobs are created informality increases and urbanization can thus be followed by a higher incidence of poverty in the non-farm urban centers. This is what may happen in Panama between 2003 and 2014: although overall poverty is reducing, by increasing informality, the process of urbanization reduces average incomes and increases poverty among non-farm informal households. This trend is reversed during period 2014 – 2020 when informality is reduced from 40 percent to 36 percent despite the continuous rural to urban migration of unskilled workers.

The welfare effects discussed so far are those that would take place between 2003 and 2020 in the BaU scenario. Consider now the Canal scenario. Model simulations show that the welfare differentials between the BaU and the Canal scenarios are negligible during the construction phase and rather small during the the first 6 years of the operation phase.

The moderate real income gain of 6 Balboas on average (Table 5) during the construction phase is explained by a rise in wages and a reallocation of workers out of agricultural sectors and into formal activities. As a consequence of the Canal construction, almost a thousand workers move out of agricultural sectors, and more than three thousand abandon informal occupations. All the movers enjoy considerable welfare gains; however, due to the small size of this group the overall distributional effect is negligible as demonstrated by no change in the Gini coefficient and the flat growth

incidence curve of Figure 5. Aggregate poverty declines marginally due to a relative increase in farm wages as a consequence of out-migration from the agricultural sector.

Figure 4 Sectoral Reallocation: Urbanization with Few Creation of Formal Jobs



The operation phase is characterized by a larger average real income gain, of about 243 Balboas, and a noticeable increase in inequality. About ten thousand individuals (or 0.3 percent of the population) escape moderate poverty, with 10 percent of it explained by labor reallocation and the rest is accounted for by the increase in wages of unskilled workers in urban areas. However, the poverty gap increases, meaning that poorer individuals are negatively affected and their incomes fall further away from the poverty line.

The increase in inequality during the Canal operation is underpinned by a contraction in real incomes of the poorest parts of the society. On the one hand, households in the left tail of the income distribution (mainly rural and indigenous communities) are mostly detached from the dynamic formal sectors in urban areas. For these households, labor remuneration accounts for as little as 30 percent of total income; the remainder is made up of remittances, government transfers, imputed rents, pensions and other transfers, none of which directly benefit from increased output of the Canal or its related activities. On the other hand, with rising goods prices – as shown by the last two rows of Table 3 – the cost of a consumption basket for these households rises.[24] Consequently, as illustrated in Figure 5**,** households in the left tail of the distribution (percentile 17 and under) suffer a real income loss of 1.3 percent relative to the BaU scenario.[25]

[24] This result should be taken with caution since we are assuming that consumption baskets are fixed although prices are changing. Moreover, the household-specific price index that we are using only allows for differences in the shares of food to non-food expenditures between households. One would expect that the basket of food consumed by the poor differ substantially from the basket of food consumed by the non-poor.

[25] Real incomes of the families under extreme poverty would increase 1 percent under the assumption that the real value of the exogenous components of income remain constant. In other words, if the government

Figure 5 Growth Incidence Curve (GIC) Canal Expansion vs. BaU in 2014 and 2020

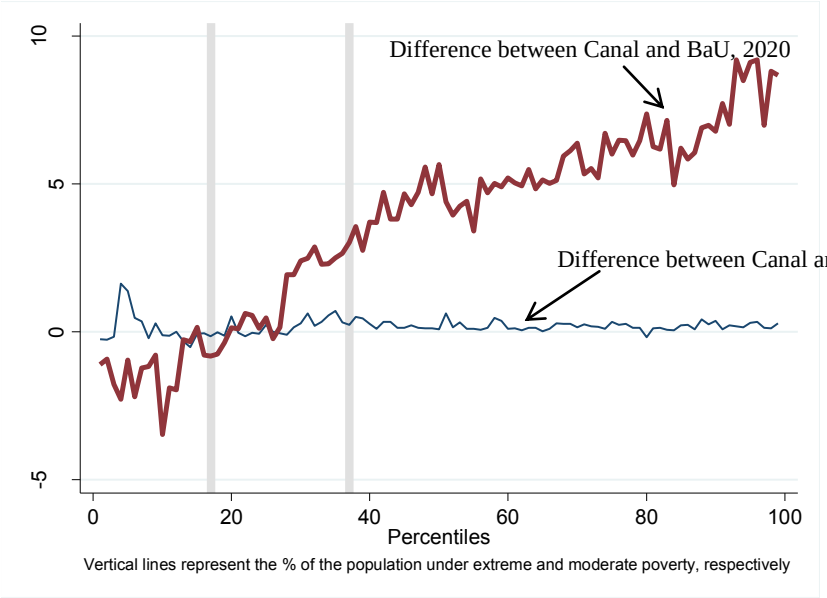
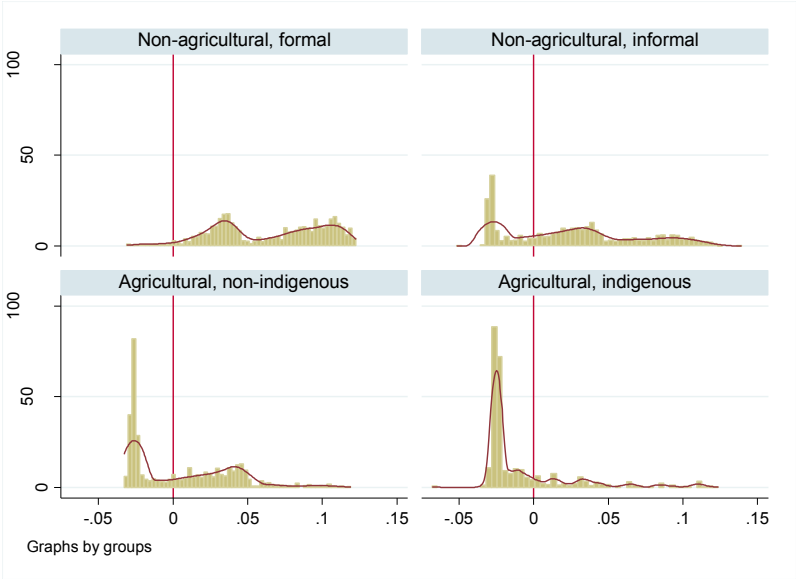


Figure 6 shows the distribution of changes in real incomes by population groups. This figure clearly illustrates that, notwithstanding the positive average change of 5 Balboas, a large share of people in the indigenous group experiences losses in the Canal scenario. This contrasts with the distribution of the gains and losses for people occupied in formal non-agricultural sectors (top left panel in the figure). For this latter group higher 'density' is concentrated in the positive portion, i.e. in the gains portion, of the horizontal axis.

Figure 6: Distribution of real income changes in 2020 (Canal – BaU)



Note: the horizontal axis represents the percent differences between households' per capita incomes in the Canal and BaU scenarios for the year 2020.

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were to compensate for the increase in prices brought about by the Canal operation, everybody would benefit from it. Nevertheless, the regressive effects of the Canal would remain (a discussion on compensatory measures is included below).

4.3. Poverty Effects of Potential Redistribution Policies

The model's results show that the Canal expansion will have a positive effect on average incomes, including government revenues. However, the distributive effects of the Canal expansion are adverse, not only increasing inequality but reducing welfare among poorest households. The unfavorable distributional effects brought about by the Canal expansion could be offset by implementing redistribution policies or strengthening existing ones. By 2020 the government of Panama gets an extra 273 million Balboas as a direct result of the rise in the Canal's transit. To put this figure in perspective, if the government of Panama wanted to eliminate extreme poverty in 2003 it would have to transfer 104 million Balboas to the poorest families; eradicating moderate poverty would cost 445 million Balboas, therefore the extra government resources generated by the Canal expansion are far from being trivial. In 2020 with the extension of the Canal in operation, eliminating extreme and moderate poverty will require a total transfer of 90 million Balboas and 350 million Balboas, respectively.

To illustrate the poverty effects of a redistribution program, we simulate a case where the entire excess revenue of the Canal (273 million Balboas) is transferred to the poorest families in Panama. The transfers are equal to the gap between per capita household consumption and the moderate poverty line; the families are sorted from the poorest to the richest and the transfers follow this order and continue until the 273 million Balboas are fully allocated. Under this simplistic redistribution policy scenario, extreme poverty would be completely eliminated, and the incidence of moderate poverty would be reduced to 13.2 percent of the population (see Table 6). In this hypothetical redistribution program, the poorest 66,425 families in Panama (including 438,766 individuals or 14 percent of the population) receive an annual transfer equal to 4,128 Balboas.

Table 6: Welfare Effects After Redistributing the Canal's Revenues

Scenarios	Average Real Income	Poverty Headcount Ratio		Gini Coefficient
		Extreme	Moderate	
Transfer equal to the moderate poverty gap (no leakage)	3,842	0	13.2	56
Transfer equal to the moderate poverty gap (with admin. Costs and 20% leakage)	3,842	3.7	18	57

This redistribution program is sufficient for a massive reduction in inequality of 3 Gini points; nevertheless, this large equalizing effect would take place under the assumption that the redistribution policy has no administrative costs and targeting is perfect (i.e. leakage is equal to zero or, in other words, no individual among the non-poor group benefits from the program). A more realistic scenario would take into account administrative costs and some degree of leakage of resources. For instance, in Panama's pilot conditional cash transfer program, *Red de Oportunidades* (RdO), 5 percent of the program's total 30 million Balboas budget is expected to be spent on administrative costs. Even under a more realistic scenario which accounts for an administrative cost of 5 percent of total budget and a leakage of, say, 20 percent, the resources available for transfer are still 204 million Balboas, enough to alleviate most of Panama's poverty. Under this more realistic scenario, extreme poverty is almost eliminated and moderate poverty is reduced to 18 percent of the population (see Table 6).

4.4. Caveats and Robustness: A brief discussion

Modeling at both the macro and micro levels the impact of a large future infrastructure project such as the Panama Canal is an extremely complicated exercise. Although every effort has been made to embed as much realism as possible while still keeping model results tractable—and the resulting effort represents the best available methodology to date for carrying out this type of analysis—the results come with a set of important caveats. They should not be interpreted as forecasts but rather as ceteris paribus scenarios where many elements of the economy were left unchanged for tractability and where some simplifying assumptions were deemed necessary.

Two key assumptions were: a) maintaining constant the composition of skills across scenarios, and b) full employment of factors. With regard to the former, although the model horizon is long enough to allow some individuals to respond to changing wage levels by investing in skills building, modeling such a response is fraught with difficulties. First, if individuals exit the labor market in order to acquire new skills, growth would suffer in the interim as labor supply would decline. The decline in growth, however, would bring with it a fall in demand for skill-intensive products which would limit somewhat the pressure on skilled wages. Second, opportunities must be available to allow an economically significant number of persons to upgrade their skills. This would normally imply an expansion in the public provision of educational services and training; in turn, such a supply response would take time and would also have to be financed. Depending on the financing vehicle, this could imply higher rates of taxation or some crowding-out of private investment, both of which would somewhat dampen growth and slow the growth in skilled wages. Therefore, given the many additional assumptions required to incorporate such a supply response, the paper does not explicitly model this possibility. However, if a sufficient number of workers were able to upgrade their skills—with limited negative spillovers for growth in the interim period—the adverse distributional effects described in this paper would be lessened.

With regard to the full employment assumption, the model could accommodate a solution with unemployment. However, we opted for a full employment closure because of the empirical evidence on the relative stability of the unemployment rate and because the economy of Panama has been growing (even before the construction phase) above its 6 percent potential growth rate and thus its recent (2007-2010) 6.5 unemployment rate can be considered structural and insensitive to increases of demand.[26] In order to check how results would change, we ran a version of the CGE model where wages are fixed and additional demand is met with additional employment, a sort of pure multiplier model. In this set-up, the construction phase would create just 0.2 percent more employment (for both skilled and unskilled workers) when compared with the BaU scenario.[27] Note that, in this case, wages do not go up, so there are incentives for firms to substitute, compatibly with a given technology, other inputs for labor. As explained above, Canal construction generates demand for construction services but also large leakages through

[26] For more details on potential growth and unemployment issues see IMF (2010). Note also that in this document IMF staff forecasts growth for Panama "to hover around 6 percent, broadly in line with current potential growth".

[27] This percentage (0.2%) is calculated as the percentage difference between the level of total employment achieved by the end of the construction phase, i.e. by 2014, and the level of employment in the BaU for the same year. It is thus equivalent to the cumulated (2004-1014) employment effect.

imports; so this small employment multiplier is not surprising. The operation phase generates a slightly larger effect with employment increasing, by the end of the projection period, by 2.5 percent. What can be expected of these quantity changes in terms of income distribution? Assuming that unemployed workers are in the lower tail of the distribution, a reduction of unemployment may have some equalizing effect. However these effects will be negligible given that only a small fraction of the population (those escaping unemployment) benefits from increased incomes. The results reported in the above sections can thus be thought of as a sort of upper bound for the changes in inequality and poverty. In an intermediate situation, where both wages and employment respond to the Canal shock, employment effects would be even smaller and the wage effects would be somewhat muted entailing once again reduced distributional impacts.[28]

There are also additional caveats to the results presented here, many of which indicate directions for future research. First, our estimates are based on a structural model and therefore are determined to a large extent by the structure of the economy in the base year. Therefore, the expanded Canal is essentially a larger version of the Canal today; it does not develop any new linkages to the rest of the economy or generate important economy-wide spillovers (productivity or otherwise). Second, although we have attempted to link the macro and micro sides of the analysis as closely as possible, a number of inconsistencies remain. Our macro analysis does not capture self-consumption or intra-household transfers, which may be particularly important for the poorest households. Similarly, our micro analysis does not take into account changes in payments to capital, which are particularly relevant to the households in the top portion of the income distribution. Thus, our poverty and inequality results pertain mainly to the changes in returns to labor. Third, even if the unemployment rate in Panama is insensitive to periods of economic boom or bust, the response among under-employed may be significant. Therefore, our analysis may ignore potentially important employment creation effects through this channel. Finally, our micro analysis focuses only on first-order effects and does not allow households to re-optimize their consumption bundle in response to aggregate price changes. Thus, we could be over-stating the losses incurred by the poorest households, since they may be able to switch to lower-cost products when prices of some food items rise.

5. Conclusions

The Panama Canal is a major source of export revenue for Panama, but its contribution to value added and employment is much more limited. Using a dynamic macro-micro framework, this paper has argued that the proposed expansion of the Canal is likely to have significant macroeconomic effects only during the operations phase (2014 and onwards), and that income gains linked to the construction and operation of the new Canal are likely to be concentrated in the top portion of the income distribution. There are three main reasons for these conclusions. First, our approach does not allow for any net employment creation from investment in the Canal; this is consistent with econometric evidence on Panama's labor markets but differs from the view adopted by several macroeconomic studies of the Canal expansion. Second, Panama may experience

[28] Notice that inequality is driven by changes in relative wages (skilled versus unskilled). In the additional CGE runs performed to test robustness of the results, the skilled premia increases less than in the standard (full employment) closure.

sizeable real exchange rate appreciation depending on the amounts of foreign borrowing during the construction phase and the larger revenues accruing from the expanded Canal service exports during the operation phase. The additional inflows of foreign currency result not only in the loss of competitiveness of non-Canal sectors (Dutch disease effect) but also in higher domestic prices which—even though the increase in non-food CPI outpaces the rise in food CPI—hurt the poorest consumers in the Panamanian society. Third, investment and operation of the expanded Canal increase demand for formal workers in non-farm activities, particularly those who have at least some secondary education. Although these changes encourage some additional movement of labor from agriculture to non-agriculture and from the informal sector to formal activities, much of the impact is manifested in growing wage disparities between the poor (agricultural, and particularly indigenous, workers) and the relatively well-off (skilled formal sector workers).

The results show that, although aggregate poverty is likely to remain unchanged as a result of the Canal project, income inequality and the poverty gap are likely to increase. In order to counteract these negative tendencies, the government could earmark some of the additional revenues of the Panama Canal Authority for funding a targeted cash transfer program. Results from an illustrative simulation show that, even allowing for imperfect targeting by allocating 5 percent of the revenues to administrative costs and another 20 percent to funds leakage, this policy action could reverse the adverse distributional impacts by almost eliminating extreme poverty and halving the moderate poverty headcount.

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Annex 1: Economic Structure of Panama

	Contribution to domestic production	Contribution to value added	Contribution to exports	Exports as a share of domestic production	Imports as a share of domestic demand	Unskill Lab. Value Added	Skilled Lab. Value Added	Capital Lab. Value Added	Inf. Capital Value Added
Canal	4.2	5.7	19.6	100.0		1	0		
Agriculture for Domestic Mkt.	3.5	3.6	0.2	1.3	12.6	17	1	3	
Agriculture for Export Mkt.	3.8	4.1	6.4	35.6	2.3	16	2	4	
Mining	1.0	1.0	0.7	13.7	51.8	0	0	2	
Manufacturing for Domestic Mkt	6.1	2.8	2.5	8.6	26.0	6	6	4	7
Manuf. for Domestic Mkt (inf.)	0.5	0.2				3	2		7
Manuf. for Domestic Mkt (for.)	5.7	2.5				3	4	4	
Manufacturing for Export Mkt	12.4	11.2	30.9	53.4	63.4	2	1	18	38
Manuf. for Export Mkt (inf.)	1.6	1.1				2	0		38
Manuf. for Export Mkt (for.)	10.8	10.1				0	0	18	
Electricity and Water	2.4	2.9	0.0	0.1	5.2	0	1	5	
Construction	7.6	4.8				7	4	4	19
Construction (inf.)	1.2	0.8				4	1		19
Construction (for.)	6.4	4.0				4	2	4	
Commerce and Other Services	11.1	9.2	0.9	1.8	0.0	35	34	5	28
Commerce Oth. Services (inf.)	2.4	2.3				24	12		28
Commerce Oth. Services (for.)	8.7	6.9				11	23	5	
Transport & Communications	8.9	9.2	22.2	53.4	12.8	5	7	9	8
Transport Communication (inf.)	1.1	1.4				4	3		8
Transport Communication (for.)	7.7	7.8				2	5	9	
Financial Services	26.1	28.3	16.7	13.6	3.4	3	11	41	
Public Administration	12.9	17.3				8	33	5	
Total	100.0	100.0	100.0	21.4	18.6				
Agriculture	7.3	7.7	6.6	19.3	8.5	33.1	3.5	7.0	0.0
Manufacturing	19.5	15.0	34.0	37.2	53.2	8.4	6.4	21.8	45.5
Services (incl. Construction & Canal)	73.2	77.3	59.4	17.3	4.9	58.3	89.9	69.5	54.5
Informal Activities (excl agriculture)	6.7	5.8				36.5	18.0	0.0	100.0
Formal Activities	86.0	86.5				30.4	78.5	93.0	0.0

Annex 2: Identifying Labor and Capital Remunerations Using Household Survey Data

In household surveys, the primary source of income information, labour remunerations and returns to capital are lumped together in the income figures reported by self-employed. In many instances it is important to distinguish the proportion of personal income of self-employed that is accrue to the individual's labour inputs from what is attributable to capital. The objective of this note is to show how to identify the value added (VA) of capital using micro data at the personal level.

Let us define the income of self-employed individuals as the sum of labour remunerations and returns to capital: $Y = Y^l + Y^k$. Assume that *A* and *B* are two randomly-drawn individuals from the population who are identical in all characteristics except for their occupational category. *A* is a wage worker and *B* is self-employed. Furthermore, assume that self-employment activities require an investment in physical capital greater than zero. Under competitive labor markets, *B* could earn a wage as high as the wage earned by *A*. Therefore a good proxy for the unobserved value of Y^l for individual *B* is the expected wage given his/her personal characteristics. Under this simple setting, income gaps between *A* and *B* are attributable to returns to physical capital.

Define wages (*w*), as the sum of personal characteristics related to labor productivity (***X***) valued at their market rate ($\boldsymbol{\beta}$) plus a random component (ε):

$$\ln(w_i) = \alpha + \sum_j \beta_j X_{i,j} + \varepsilon_i \qquad (1)$$

where $\varepsilon \sim N(0, \sigma^2)$ and $i \in (earner)$. The parameters in equation (1) can be use to estimate the expected value of the log of labor income for self-employed workers, if and only if the wage equation parameters apply to out-of-sample observations. A necessary condition to fulfill this requirement is that the partition between wage workers and self-employed is the outcome of a random process. In other words, workers in the wage-earning sectors should be *similar* once controlling for X_j, than self-employed workers. If this condition is not met and wage workers are distinguished by certain unobservable characteristic that makes them *self-select* into the wage-earning sectors, β_j cannot be use to obtain an estimate of labor remunerations for the self-employed. A simple modification to equation (1) can correct for the selection problem (Heckman, 1979):

$$\ln(w_i) = \alpha^* + \sum_j \beta_j^* X_{i,j} + \lambda \frac{\phi(Z)}{\Phi(-Z_i)} + \varepsilon_j^* \qquad (2)$$

where ***Z*** is a vector with the variables determining the probability of being a wage worker; $\phi(\bullet)$ and $\Phi(\bullet)$ represent the probability and cumulative normal distribution functions, respectively; and (α^*, β^*) are the parameters for the *population* regression model. Notice that vector ***Z*** contains all personal characteristics ***X*** plus, at least, one extra

variable (instrument) which is not related to wages but, nevertheless, affects the probability of becoming a wage worker. Our hypothesis is that the decision to whether to be a wage worker or an earner is a result of the agent's risk aversion. Controlling for other personal characteristics, more risk-averse individuals will tend to choose the earnings sector as the preferred option. Savings can serve as a good proxy for risk aversion; risk-averse individuals would show higher savings rates than risk-lovers. Therefore higher saving rates, which proxy for higher risk aversion, should be positively related with the probability of being wage worker. The population parameters (α^*, β^*) can be use to assign the expected value of earnings for self-employed workers:

$$E\left[\ln(Y_g^l) \mid X_g\right] = \hat{\alpha}^* + \sum_j \hat{\beta}_j^* X_{g,j} \qquad (3)$$

where $E[\bullet]$ is the expectations operator, $\hat{\alpha}^*$ and $\hat{\beta}^*$ are the *population* parameters estimated from equation (2), and $g \in$ *(self-employed)*. To get the expected value of labor income in levels, Y^l:

$$\hat{Y}_g^l = E\left[Y_g^l \mid X_g\right] = \exp\left\{E\left[Y_g^l \mid X_g\right]\right\} * \exp\left\{\sigma^2 / 2\right\} \qquad (4)$$

where element $\exp\left\{\sigma^2 / 2\right\}$ is a scaling-up factor equal to $E[\exp\{\varepsilon^*\}] \Leftrightarrow \varepsilon \sim N(0, \sigma^2)$, see Wooldridge, 2003, pg. 207.[29] If $\hat{\alpha}^*$ and $\hat{\beta}^*$ are unbiased *population* parameters, $E\left[(Y_g^l - \hat{Y}_g^l) \mid X_g\right] = 0$ and it follows that:

$$\hat{Y}_g^k = Y_g - \hat{Y}_g^l \qquad (5)$$

[29] If ε does not follow a normal distribution, the scaling-up factor can be estimated by running a *simple* regression of w_i on $\exp\{E[\ln(w_i)]\}$ without an intercept and using the only estimated parameter as the correction factor.

Annex 3: Micro-model Regression Results

Mincer Equation Results for the Different Labor Market Segments

	Agricultural Sectors	Non-Agricultural Sectors	Informal Activities in Non-Agricultural Sectors	Formal Activities in Non-Agricultural Sectors
	lnY_lab			
Urban	0.344	0.191	0.099	0.167
	(3.04)**	(5.55)**	-1.86	(4.13)**
Household Head	0.317	0.306	0.237	0.261
	(2.97)**	(9.10)**	(4.03)**	(7.17)**
Gender	0.193	0.237	0.187	0.123
	-0.95	(7.64)**	(3.61)**	(3.54)**
Years of Schooling	0.011	0.058	0.114	0.008
	-0.3	(3.95)**	(4.65)**	-0.4
Years of Schooling Sq	0.006	0.005	-0.001	0.005
	(2.61)**	(7.62)**	-0.53	(6.66)**
Experience	0.088	0.080	0.085	0.066
	(8.98)**	(25.74)**	(17.33)**	(17.57)**
Experience Squared	-0.001	-0.001	-0.001	-0.001
	(7.85)**	(18.91)**	(12.95)**	(12.02)**
Constant	5.113	5.078	4.624	6.179
	(19.32)**	(57.91)**	(36.65)**	(50.75)**
Observations	997	6907	2793	4114
Adjusted R-squared	0.18	0.33	0.19	0.28

Absolute value of t statistics in parentheses
* significant at 5%; ** significant at 1%

Probit Estimation of the Probability of a Worker Changing Sector of Employment

	Movement from Agricultural to Non-Agricultural Sectors	Movement from Informal to Formal Activities
Urban	-1.463 (309.49)**	-0.324 (64.32)**
Household Head	0.180 (31.54)**	-0.359 (66.20)**
Gender	1.197 (186.35)**	-0.689 (123.53)**
Years of Schooling	-0.139 (147.78)**	-0.041 (40.62)**
Experience	-0.012 (24.96)**	-0.034 (64.00)**
Experience Squared	0.000 (23.66)**	0.001 (79.14)**
Household Members	0.024 (32.35)**	-0.006 (6.62)**
Self-employed	0.403 (89.11)**	
Other HH member's income	0.000 (16.10)**	
Sectoral Dummies		YES
Constant	-0.354 (29.53)**	1.830 (140.72)**
Observations	5762	3201
Pseudo-R2	0.41	0.12

Absolute value of z statistics in parentheses
* significant at 5%; ** significant at 1%

Annex 4: Sectors and commodities in the Panama SAM

Production Sectors		Commodities
Formal Sectors	**Informal Sectors**	
Canal		Canal
Agriculture for Domestic Mkt.		Maize Rice Oil Seeds Swine Livestock Poultry Livestock Milk Other Domestic Agriculture Products
Agriculture for Export Mkt.		Other Livestock Fruits Fish Products Shellfish Other Exports Agriculture Products
Mining		Mining Products
Manuf. for Domestic Mkt (for.)	Manuf. for Domestic Mkt (inf.)	Meat Dairy Grain Products Other Domestic Manufacturing
Manuf. for Export Mkt (for.)	Manuf. for Export Mkt (inf.)	Textiles Raw Products Textiles Clothing Leather Other Export Manufacturing
Electricity and Water		Electricity and Water
Construction (for.)	Construction (inf.)	Construction
Commerce Oth. Services (for.)	Commerce Oth. Services (inf.)	Commerce and Other Services
Transport Communication (for.)	Transport Communication (inf.)	Transport Communication
Financial Services		Financial Services
Public Administration		Public Administration

Annex 4: Equations of the CGE model

Demand for intermediate inputs bundle
$$ND_i = \alpha_i^{nd}\left(\frac{PX_i}{PND_i}\right)^{\sigma_i^p} XP_i$$

Demand for value added
$$VA_i = \alpha_i^{va}\left(\frac{PX_i}{PVA_i}\right)^{\sigma_i^p} XP_i$$

Output price
$$PX_i = \left[\alpha_i^{nd} PND_i^{1-\sigma_i^p} + \alpha_i^{va} PVA_i^{1-\sigma_i^p}\right]^{1/(1-\sigma_i^p)}$$

Producer price
$$PP_i = \left(1+\tau_i^p\right) PX_i$$

Demand for intermediate inputs by good
$$XA_{k,j} = a_{k,j}\left(\frac{PND_j}{PA_{k,j}}\right)^{\sigma_j^n} ND_j$$

Price of intermediate goods bundle
$$PND_j = \left[\sum_k a_{k,j}\left(PA_{k,j}\right)^{1-\sigma_j^n}\right]^{1/(1-\sigma_j^n)}$$

Demand for unskilled labor bundle
$$UL_i = \alpha_i^u\left(\frac{PVA_i}{PUL_i}\right)^{\sigma_i^{kl}} VA_i$$

Demand for capital-skilled labor bundle
$$KSK_i = \alpha_i^{ksk}\left(\frac{PVA_i}{PKSK_i}\right)^{\sigma_i^{kl}} VA_i$$

Price of value added
$$PVA_i = \left[\alpha_i^u PUL_i^{1-\sigma_i^{kl}} + \alpha_i^{ksk} PKSK_i^{1-\sigma_i^{kl}}\right]^{1/(1-\sigma_i^{kl})}$$

Demand for skilled labor bundle
$$SKL_i = \alpha_i^s\left(\frac{PKSK_i}{PSKL_i}\right)^{\sigma_i^{ks}} KSK_i$$

Demand for capital
$$K_i^d = \alpha_i^k\left(\lambda_i^k\right)^{\sigma_i^k-1}\left(\frac{PKSK_i}{R_i}\right)^{\sigma_i^k} KSK_i$$

Price of capital-skilled labor bundle
$$PKSK_i = \left[\alpha_i^s PSKL_i^{1-\sigma_i^{ks}} + \alpha_i^k\left(\frac{R_i}{\lambda_i^k}\right)^{1-\sigma_i^k}\right]^{1/(1-\sigma_i^{ks})}$$

Demand for unskilled labor by type
$$L_{i,ul}^d = \alpha_{i,ul}^l\left(\lambda_{i,ul}^l\right)^{\sigma_i^u-1}\left(\frac{PUL_i}{W_{i,ul}}\right)^{\sigma_i^u} UL_i$$

Demand for skilled labor by type
$$L_{i,sl}^d = \alpha_{i,sl}^l\left(\lambda_{i,sl}^l\right)^{\sigma_i^s-1}\left(\frac{PSKL_i}{W_{i,sl}}\right)^{\sigma_i^s} SKL_i$$

Price of unskilled labor bundle

$$PUL_i = \left[\sum_{ul \in \{\text{Unskilled labor}\}} \alpha^l_{i,ul} \left(\frac{W_{i,ul}}{\lambda^l_{i,ul}} \right)^{1-\sigma^u_i} \right]^{1/(1-\sigma^u_i)}$$

Price of skilled labor bundle

$$PSKL_i = \left[\sum_{sl \in \{\text{Skilled labor}\}} \alpha^l_{i,sl} \left(\frac{W_{i,sl}}{\lambda^l_{i,sl}} \right)^{1-\sigma^s_i} \right]^{1/(1-\sigma^s_i)}$$

Labor income

$$LY_l = \sum_i NW_{i,l} L^d_{i,l} + ER.FW_l$$

Capital income

$$KY = \sum_i NR_i K^d_i \qquad \text{(Y-4)}$$

Profits

$$Prof^c_e = \left(1 - \kappa^c_e\right)\left(KY + ER.TR_{W,e} + r^g_d GDebt\right)$$

Corporate saving

$$S^c_e = s^c_e Prof^c_e$$

Corporate transfers to households

$$TR^H_{c,e} = Prof^c_e - S^c_e$$

Household disposable income

$$YD_h = \left(1 - \lambda^h \kappa^h_h\right)\left(\underbrace{\sum_l \varphi^h_{l,h} LY_l}_{\text{Labor}} + \underbrace{\sum_e \varphi^h_{e,h} TR^H_{c,e}}_{\text{Enterprise}} + \underbrace{PLEV.TR^H_{g,h}}_{\text{Transfers from government}} + \underbrace{ER.TR^h_{W,h}}_{\text{Foreign remittances}} \right)$$

Household consumption

$$XA_{k,h} = Pop_h \theta_{k,h} + \frac{\mu_{k,h}}{PAc_{k,h}} \left((1 - s^h_h) YD_h - \sum_{k'} PAc_{k',h} Pop_h \theta_{k',h} \right)$$

Household saving

$$S^h_h = YD_h - \sum_k PAc_{k,h} XA_{k,h}$$

Household consumer price index

$$CPI_h = \frac{\sum_k PAc_{k,h} XA_{k,h,0}}{\sum_k PAc_{k,h,0} XA_{k,h,0}}$$

Consumer price

$$PAc_{k,h} = PA_{k,h}(1 + \tau^c_{k,h})$$

Non-household final demand

$$XA_{k,f} = \alpha^f_{k,f} \left(\frac{PF_f}{PA_{k,f}} \right)^{\sigma^f_f} XF_f$$

Non-household final demand price

$$PF_f = \left[\sum_k \alpha^f_{k,f} \left(PA_{k,f} \right)^{1-\sigma^f_f} \right]^{1/(1-\sigma^f_f)}$$

Value of final demand

$$YF_f = PF_f XF_f$$

Demand for domestically produced goods

$$XD^d_{k,a} = \alpha^d_{k,a} \left(\frac{PA_{k,a}}{PD_k \ (1 + \tau^{cd}_{k,a})} \right)^{\sigma^m_{k,a}} XA_{k,a}$$

Demand for foreign-produced goods	$XMT_{k,a} = \alpha_{k,a}^{m} \left(\frac{PA_{k,a}}{(1+\tau_{k,a}^{cm}) PMT_{k,a}} \right)^{\sigma_{k,a}^{m}} XA_{k,a}$
Armington price	$PA_{k,a} = \left[\alpha_k^d \left(PD_k \ (1+\tau_{k,a}^{cd}) \right)^{1-\sigma_{k,a}^{m}} + \alpha_k^m \left((1+\tau_{k,a}^{cm}) \ PMT_{k,a} \right)^{1-\sigma_{k,a}^{m}} \right]^{1/(1-\sigma_{k,a}^{m})}$
Import price (domestic currency)	$PM_{k,r} = ER.WPM_{k,r}$
Import demand	$XM_{k,r} = \alpha_{k,r}^{w} \left(\frac{PMT_{k,a}}{PM_{k,r}} \right)^{\sigma_{tr,k}^{w}} \sum_a XMT_{k,a}$
Export price (domestic currency)	$PE_{k,r} \ (1+\tau_{k,r}^{e}) = ER.WPE_{k,r}$
Supply of home produced goods for domestic market	$XD_k^s = \gamma_k^d \left(\frac{PD_k}{P_k} \right)^{\sigma_k^x} X_k$
Supply of home produced goods for exports	$XET_k = \gamma_k^e \left(\frac{PET_k}{P_k} \right)^{\sigma_k^x} X_k$
Output price	$P_k = \left[\gamma_k^d PD_k^{1+\sigma_k^x} + \gamma_k^e PET_k^{1+\sigma_k^x} \right]^{1/(1+\sigma_k^x)}$
Export volume	$XE_{k,r} = \gamma_{k,r}^{x} \left(\frac{PE_{k,r}}{PET_k} \right)^{\sigma_k^z} XET_k$
Export price	$PET_k = \left[\sum_r \gamma_{k,r}^{x} PE_{k,r}^{1+\sigma_k^z} \right]^{1/(1+\sigma_k^z)}$
Export demand	$\begin{cases} ED_{k,r} = \alpha_{k,r}^{e} \left(\frac{\overline{WPE}_{k,r}}{WPE_{k,r}} \right)^{\eta_{k,r}^{e}} (1+g_r^{w})^{\eta_{k,r}^{w}} & \text{if} \quad \eta_{k,r}^{e} \neq \infty \\ WPE_{k,r} = \overline{WPE}_{k,r} & \text{if} \quad \eta_{k,r}^{e} = \infty \end{cases}$
Equilibrium conditions	$X_k = \sum_{i \in K} XP_{i,}$
	$P_k = \sum_{i \in K} PP_{i,}$
	$\sum_a XD_{k,a}^{d} = XD_k^s$
	$ED_{k,r} = XE_{k,r}$

Government income

$$GY = \underbrace{\sum_k \sum_a \tau^{cd}_{k,a}(PD_k + PTMG_k \tau^{mg,D}_{k,a}) XD^d_{k,a}}_{\text{Sales tax on demand for domestic goods}} + \underbrace{\sum_k \sum_a \tau^{cm}_{k,a} PMT_{k,a} XMT_{k,a}}_{\text{Sales tax on demand for import goods}}$$
$$+ \underbrace{\sum_l \sum_i (\tau^{xfl}_{i,l} + \tau^{sfl}_{i,l}) NW_{i,l} L^d_{i,l}}_{\text{Wage tax and subsidies}} + \underbrace{\sum_e \kappa^c_e CY_e}_{\text{Corporate tax}} + \underbrace{\lambda^h \sum_h \kappa^h_h YH_h}_{\text{Income tax}} + \underbrace{ER.TR^g_W}_{\text{Transfers from ROW}}$$
$$+ \underbrace{\sum_i \tau^p_i PX_i XP_i}_{\text{Production tax}} + \underbrace{ER. \sum_{md} \sum_k \sum_r \tau^m_{k,r,md} WPM_{k,r} XM_{k,r}}_{\text{Import distortions}}$$

Government expenditure

$$GEXP = YF_{Govnt} + PLEV \sum_h TR^H_{g,h} + ER.TR^W_g + r^g_d Debt^g_d + r^g_f Debt^g_f .ER$$

Government saving

$$S^g = GY - GEXP$$

Savings-investment balance

$$YF_{Invst} + YF_{Ginvst} = \sum_e S^c_e + \sum_h S^h_h + S^g + ER.BOR^g_f + ER.S^p_f + ER.FDI$$

Volume of gov. consumption

$$XF_{Govnt} = \alpha_{Govnt} (RGDPMP)^{\eta^g}$$

Volume of gov. investment

$$XF_{GInvst} = \alpha_{GInvst} (RGDPMP)^{\eta^{zg}}$$

Armington price index

$$PLEV = \frac{\sum_a \sum_k PA_{k,a} XA_{k,a,0}}{\sum_a \sum_k PA_{k,a,0} XA_{k,a,0}}$$

Rural labor supply

$$L^s_{l,Rur} = (1 + g^L_{l,Rur}) L^s_{l,Rur,-1} - MIGR_l$$

Urban labor supply

$$L^s_{l,Urb} = (1 + g^L_{l,Urb}) L^s_{l,Urb,-1} + MIGR_l$$

Total labor supply

$$L^s_{l,Tot} = \sum_{gs} L^s_{l,gs}$$

Rural-urban wages

$$AWAGE_{l,gz} = (1 - UE_{l,gz}) \frac{\sum_{i \in gz} NW_{i,l} L^d_{i,l}}{\sum_{i \in gz} L^d_{i,l}}$$

Rural-urban migration

$$MIGR_l = \chi^{migr}_l \left(\frac{AWAGE_{l,Urb}}{AWAGE_{l,Rur}} \right)^{\omega^m_l} \quad \text{if} \quad \omega^m_l \neq \infty$$

Wage by sector

$$NW_{i,l} = \phi^l_{i,l} W^e_{i,gz} \quad \text{for} \quad i \in gz$$

Post-tax wage by sector

$$W_{i,l} = (1 + \tau^{xfl}_{i,l} + \tau^{sfl}_{i,l}) NW_{i,l}$$

Capital supply by sector

$$K^s_i = \gamma^k_i \left(\frac{NR_i}{PK} \right)^{\omega^k} TK^s$$

Price of capital	$PK = \left[\sum_i \gamma_i^k NR_i^{1+\omega^k} \right]^{1/(1+\omega^k)}$
Capital equilibrium condition	$K_i^s = K_i^d$
Foreign saving	$S_f = S_f^g + S_f^p$
Government domestic borrowing	$BOR_d^g = \chi_g \left(YF_{ginvst} - S_g \right)$ $BOR_d^g = \sum_e S_e^c$
Government saving-investment	$YF_{Ginvst} = S^g + BOR_d^g + ER.BOR_f^g$
Debt dynamics	$Debt_d^g = Debt_{d,-1}^g + BOR_d^g$ $Debt_f^g = Debt_{f,-1}^g + BOR_f^g$ $Debt_f^p = Debt_{f,-1}^p + S_f^p$ $Debt^g = Debt_d^g + ER.Debt_f^g$
GDP at current prices	$GDPMP = \sum_k \sum_h PAc_{k,h} XA_{k,h} + \sum_k \left[PA_{Invst} XA_{Invst} + PA_{Ginvst} XA_{Ginvst} \right] + \sum_k PA_{Govnt} XA_{Govnt} + ER \sum_k \sum_r \left(WPE_{k,r} XE_{k,r} - WPM_{k,r} XM_{k,r} \right)$
GDP at base year prices	$RGDPMP = \sum_k \sum_h PAc_{0,k,h} XA_{k,h} + \sum_k \left[PA_{0,Invst} XA_{Invst} + PA_{0,Ginvst} XA_{Ginvst} \right] + \sum_k PA_{0,Govnt} XA_{Govnt} + ER_0 \sum_k \sum_r \left(WPE_{0,k,r} XE_{k,r} - WPM_{0,k,r} XM_{k,r} \right)$
GDP deflator	$PGDPMP = GDPGMP / RGDPMP$
GDP at factor cost	$GDPFC = \sum_l \sum_i W_{i,l} L_{i,l}^d + \sum_k \sum_i R_i K_i^d$
GDP growth	$RGDPMP = (1 + g^y)\ RGDPMP_{-1}$
Productivity	$\lambda_{ip,l}^l = (1 + \gamma^l + \chi_{ip,l}^l)\ \lambda_{ip,l,-1}^l$
Capital stock growth	$TK^s = TK_{-1}^s + XF_{Invst}$

Table A.4.1: Indices used in the model

i	Production activities
k	Commodities
l	Labor skills
ul	Unskilled labor
sl	Skilled labor[a]
kt	Capital types
lt	Land types
e	Corporations
gz	Geographic zones (rural, urban, national)
h	Households
f	Final demand accounts[b]
a	Armington agents[c]
r	Trading partners

Notes: a. The unskilled and skilled labor indices, *ul* and *sl*, are subsets of *l*, and their union composes the set indexed by *l*.

b. The standard final demand accounts are government current and capital expenditures and private investment.

c. The index *a* is the union of production activities, *i*, households, *h*, and other final demand accounts, *f*.

Table A.4.2: Endogenous variables

Production

ND_i	`nd(i)`	Demand for aggregate intermediate demand bundle
VA_i	`va(i)`	Demand for value added bundle
PX_i	`px(i)`	Producer price net of production tax
PP_i	`pp(i)`	Producer price
$XA_{k,j}$	`xa(k,j)`	Intermediate demand for goods and services
PND_i	`pnd(i)`	Price of aggregate intermediate demand bundle
KL_i	`kl(i)`	Demand for capital-labor bundle
NR_i^d	`rd(i)`	Demand for sector-specific resource
PVA_i	`pva(i)`	Price of value added bundle
UL_i	`usk(i)`	Demand for aggregate unskilled labor bundle
KSK_i	`ksk(i)`	Demand for capital/skilled labor bundle
PKL_i	`pkl(i)`	Price of capital-labor bundle
SKL_i	`skl(i)`	Demand for aggregate unskilled labor bundle
KT_i^d	`ktd(i)`	Demand for aggregate capital bundle
$PKSK_i$	`pksk(i)`	Price pf capital/skilled labor bundle
$LV_{i,l}^d$	`ldv(i,l)`	Sectoral variable demand for labor by labor type
PUL_i	`pusk(i)`	Price of aggregate unskilled labor bundle
$PSKL_i$	`pskl(i)`	Price of aggregate skilled labor bundle
$L_{i,l}^d$	`ld(i,l)`	Sectoral total demand for labor by labor type
PKT_i	`pktd(i)`	Price of aggregate capital demand bundle
$K_{i,kt}^d$	`kd(i,kt)`	Sectoral total demand for capital by capital type
XP_i	`xp(i)`	Aggregate output from activity *i*.

Income distribution

LY_l	`ly(l)`	Aggregate net labor remuneration
KY_{kt}	`ky(kt)`	Aggregate after-tax capital income
$TR^E_{k,kt}$	`ktre(kt)`	Capital income transferred to enterprises
CY_e	`cy(e)`	Corporate income
S^c_e	`savc(e)`	Corporate retained earnings
$TR^H_{c,e}$	`ctrh(e)`	Corporate earnings transferred to households
YD_h	`yd(h)`	Disposable income net of taxes and transfers
TR^H_h	`htr(h)`	Aggregate transfers by households
TR^W_h	`htrw(h)`	Household transfers abroad

Domestic demand variables

$XA_{k,h}$	`xa(k,h)`	Household demand for goods and services
S^h_h	`savh(h)`	Household savings
CPI_h	`cpi(h)`	Household-specific consumer price index
$PAc_{k,h}$	`pac(k,h)`	Consumer prices
$XAf_{k,f}$	`xaf(k,f)`	Other domestic final demand for goods and services
PF_f	`pf(f)`	Other domestic final demand price deflator
YF_f	`yf(f)`	Other domestic final demand aggregate expenditure level

Trade variables

$XD^d_{k,a}$	`xdd(k,a)`	Domestic demand for domestic production
$XMT_{k,a}$	`xmt(k,a)`	Domestic demand for aggregate imports
$PA_{k,a}$	`pa(k,a)`	Price of Armington good
$PM_{tr,k,r}$	`pm(tr,k,r)`	Domestic tariff-inclusive price of imports by region of origin
$XM_{tr,k,r}$	`xm(tr,k,r)`	Import demand by region of origin and tariff regime
$PMT_{k,a}$	`pmt(k,a)`	Price of imports by Armington agent
$PE_{k,r}$	`pe(k,r)`	Producer price of exports by region of destination
XD^s_k	`xds(k)`	Domestic output sold domestically
XET_k	`xet(k)`	Aggregate export supply
X_k	`x(k)`	Aggregate output
$XE_{k,r}$	`xe(k,r)`	Export supply by region of destination
PET_k	`pet(k)`	Price of aggregate exports
$ED_{k,r}$	`ed(k,r)`	Demand for exports by region of destination

Goods price equilibrium

PD_k	`pd(k)`	Price of domestic goods sold domestically
$WPE_{k,r}$	`wpe(k,r)`	World price of exports by region of destination

Macro variables

GY	`gy`	Government revenues
$GEXP$	`gexp`	Total government current expenditures
S^g	`savg`	Nominal government savings
λ^h	`dirtxhadj`	Household direct tax schedule shifter
XF_{Invst}	`xf("invst")`	Volume of private investment
$PLEV$	`Plev`	Absorption price deflator
$CPIT$	`Cpit`	Aggregate consumer price deflator

Factor market variables

$L^s_{l,gz}$	`ls(l,gz)`	Labor supply
$AWAGE_{l,gz}$	`awage(l,gz)`	Expected average wage rate
$MIGR_l$	`migr(l)`	Rural to urban migration
$WMIN_{l,gz}$	`wmin(l,gz)`	Minimum wage
$W^e_{l,gz}$	`ewage(l,gz)`	Equilibrium wage rate
$NW_{i,l}$	`nwage(i,l)`	Sector specific wage rate net of wage tax
$W_{i,l}$	`wage(i,l)`	Sector specific wage rate
TK^s_{kt}	`tks(kt)`	Aggregate capital supply by type
PK	`pk`	Economy-wide aggregate rate of return to capital
$K^s_{i,kt}$	`ks(i,kt)`	Sectoral capital supply by type
PTK_{kt}	`ptks(kt)`	Economy-wide aggregate rate of return to capital by type
$NR_{i,kt}$	`nrent(i,kt)`	Sectoral rate of return to capital by type net of tax
$R_{i,kt}$	`rent(i,kt)`	Sectoral rate of return to capital by type

Macroeconomic variables

$GDPMP$	`gdpmp`	Nominal GDP at market price
$RGDPMP$	`rgdpmp`	Real GDP at market price
$PGDPMP$	`pgdpmp`	GDP at market price deflator
$GDPFC$	`gdpfc`	Nominal GDP at factor cost
$RGDPFC$	`rgdpfc`	Real GDP at factor cost
$PGDPFC$	`pgdpfc`	GDP at factor cost deflator

Growth variables

g^y	`ggdp`	Growth rate of real GDP
$\lambda^l_{ip,l}$	`lambdal(ip,l)`	Sector- and labor-specific growth factor

Table A.4.3: Exogenous variables

Growth factors

γ^{l}	`gl`	Economy-wide labor productivity growth
$\lambda^{k}_{i,kt}$	`lambdak(i,kt)`	Capital productivity factor
$\lambda^{t}_{i,lt}$	`lambdat(i,lt)`	Land productivity factor
λ^{nr}_{i}	`lambdar(i)`	Sector-specific factor productivity
K^{s}	`ksup`	Aggregate (normalized) capital stock
$LAND$	`land`	Aggregate land supply

Trade prices

$WPM_{k,r}$	`wpm(k,r)`	World price of imports (CIF)
$\overline{WPE}_{k,r}$	`wpendx(k,r)`	Export price index of competitors
ER	`er`	Exchange rate and model numéraire

Fiscal variables

XF_{Govnt}	`xf("govnt")`	Volume of government expenditures on goods and services
τ^{p}_{i}	`tp(i)`	Production tax
$\tau^{cd}_{k,a}$	`tcd(k,a)`	Sales tax on domestic goods
$\tau^{cm}_{k,j}$	`tcm(k,a)`	Sales tax on import goods
$\tau^{c}_{k,h}$	`Hldts(k,h)`	Subsidies on household consumption
κ^{h}_{h}	`kappah(h)`	Initial marginal direct tax rates
$TR^{H}_{g,h}$	`gtrh(h)`	Transfers from government to households
κ^{c}_{e}	`kappac(e)`	Corporate tax rates
χ_{md}	`imptxadj(md)`	Uniform tariff adjustment factor
$\tau^{m}_{tr,k,r,md}$	`tm(tr,k,r,md)`	Sectoral tariffs by region of origin and tariff regime
$\tau^{e}_{k,r}$	`te(k,r)`	Sectoral export taxes by region of destination
$\tau^{xfl}_{i,l}$	`txfl(i,l)`	Wage tax by sector and labor type
$\tau^{xfk}_{i,kt}$	`txfk(i,kt)`	Capital tax by sector and capital type
$\tau^{sfl}_{i,l}$	`tsfl(i,l)`	Wage subsidy by sector and labor type
$\tau^{sfk}_{i,kt}$	`tsfk(i,kt)`	Capital subsidy by sector and capital type